

Attachment 7

**EDF-ER-245, Revision 0, OU 5-12 Phase II Soil Removal –
Global Positioning Radiometric Scanner System Calibration
for Use at ARA-23**

Document ID: INEEL/EXT-2000-01432
EDF-ER-245
Revision ID: 0
Effective Date: December 20, 2000

Engineering Design File

OU 5-12 Phase II Soil Removal – Global Positioning Radiometric Scanner System Calibration for Use at ARA-23

INEEL

Idaho National Engineering & Environmental Laboratory
BECHTEL BWXT IDAHO, LLC

Form 412.14
10/05/99
Rev. 02

1. Project File No. ARA-01, 12, & 23 2. Project/Task OU 5-12 RD/RA

3. Subtask OU 5-12 RD/RA Phase II Work Plan

4. Title: OU 5-12 Phase II Soil Removal – Global Positioning Radiometric Scanner System Calibration for Use at ARA-23

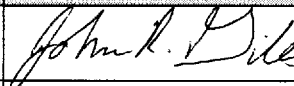
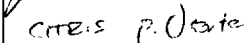
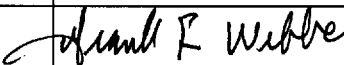
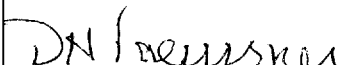
5. Summary:

A field study was conducted at the ARA-23 CERCLA site to calibrate the INEEL Global Positioning Radiometric Scanner System (GPRS). The field study resulted in the development of a calibration equation to convert net count rate data from the GPRS to Cs-137 concentrations at the ARA-23 site. Additionally, a lower limit of detection (referred to as the scan MDC) for Cs-137 for the GPRS was calculated at a value of 1.01 pCi/g. An evaluation of the GPRS accuracy with respect to the ISO-CART system shows that the GPRS is within 25% of the reported ISO-CART values. The linear calibration function and the lower limit of detection show that the GPRS is a suitable technology for the rapid field screening of Cs-137 contaminated soils at the ARA-23 site. It is cautioned that the data presented in this EDF are site specific for the ARA-23 site, and should not be arbitrarily applied to other radiologically contaminated sites; however, the method presented herein could be used to develop a site specific calibration provided that the site meets certain criteria. It is also recommended that the GPRS background be reevaluated just prior to deployment for the OU 5-12 soil removal.

6. Distribution (complete package): John R. Giles, MS 3950; Frank Webber, MS 3950; Chris Hiaring, MS 3950; Doug Preussner, MS 3950; Carol Hathaway, MS 1117

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Performer	R	John R. Giles/WAG 5 Technical Task Manager		12/13/00
Independent Reviewer	R	Chris Oertel Technical Lead, Radioanalytical Labs		12/13/00
Requestor	A	Frank L. Webber/WAG 5 Project Manager		12/13/00
Approver	A	Doug Preussner/WAG 5 Project Engineer		12/13/00

CONTENTS

ACRONYMS	v
1. INTRODUCTION	1
1.1 Source, Nature and Extent of Contamination	1
2. OBJECTIVES	1
3. METHODS AND MATERIALS	4
3.1 INEEL Global Positioning Radiometric Scanner System	4
3.2 ORTEC ISO-CART	4
3.3 Calibration Measurement Methods	4
3.3.1 GPRS Background Data Collection	4
3.3.2 Calibration Measurement Point Selection	5
3.3.3 Calibration Measurements	7
3.4 Data Reduction	7
4. RESULTS AND DISCUSSION	8
4.1 GPRS Background Determination	8
4.2 GPRS Cs-137 Calibration Curve	10
4.3 GPRS Calibration Accuracy	20
4.4 GPRS Scan MDC	20
5. SUMMARY AND RECOMMENDATIONS	25
6. REFERENCES	26

FIGURES

1. ARA-23 CERCLA site and gamma survey results	3
2. Detail of study area showing calibration measurement point locations	6
3. GPRS background count rate distribution	9
4. Transect A single-point versus five-point average count rate comparison	11
5. Transect B single-point versus five-point average count rate comparison	13

6.	Transect A detail with GPRS count rate and ISO-CART results.....	14
7.	Transect B detail with GPRS count rate and ISO-CART results.....	15
8.	GPRS calibration curve, Transect A and Transect B data combined.....	17
9.	Comparison of GPRS and ISO-CART Cs-137 concentrations.....	22

TABLES

1.	Calibration measurement point coordinate data.....	5
2.	Statistical summary of background data set.....	10
3.	Calibration point data values	18
4.	GPRS calibration accuracy	23

ACRONYMS

ARA	Auxiliary Reactor Area
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
DOE-ID	Department of Energy Idaho Operations Office
EDF	Engineering Design File
EML	Environmental Measurements Laboratory
GPRS	Global Positioning Radiometric Scanner System
INEEL	Idaho National Engineering and Environmental Laboratory
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
NRC	Nuclear Regulatory Commission
OU	operable unit

OU 5-12 Phase II Soil Removal – Global Positioning Radiometric Scanner System Calibration for Use at ARA-23

1. INTRODUCTION

This engineering design file (EDF) presents the radiation measurements and data analysis in support of a site specific field calibration of the Idaho National Engineering and Environmental Laboratory (INEEL) Global Positioning Radiometric Scanner System (GPRS) using the ORTEC ISO CART system. The primary basis for performing the equipment measurements and calibration is to demonstrate the utility of in-situ real-time measurement systems, and benchmark their use in remedial activities at a large contaminated soil area site at the INEEL. The OU 5-12 Phase II Work Plan (DOE-ID 2000a), OU 5-12 Phase II Field Sampling Plan (DOE-ID 2000b), and the OU 5-12 Soil Volume minimization strategy (INEEL 2000) detail the use of in-situ radiological measurement systems during the cleanup of Auxiliary Reactor Area (ARA)-23 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site.

1.1 Source, Nature and Extent of Contamination

The ARA-23 site is a large, roughly oval-shaped windblown contamination site encompassing the SL-1 Burial Ground and the remnants of the ARA-I and ARA-II facilities (see Figure 1). The long axis of the site is consistent with the generally southwest to northeast winds common on the INEEL. Soils were radiologically contaminated by the 1961 SL-1 accident and subsequent cleanup. Minor amounts of contamination may have been added by other ARA operations. Over time, winds dispersed the contamination over an area roughly 240 acres in size.

A Track 1 investigation was initiated for ARA-23 in 1993 but was not finalized because the site was reassigned to OU 10-06 for evaluation. The OU 10-06 evaluation, which excluded the areas within the ARA-I and ARA-II facility fences, was only partially completed before ARA-23 was reassigned to WAG 5 for final disposition. The data gaps identified in the WAG 5 Work Plan (DOE-ID 1997b) comprised the horizontal and vertical extent of Cs-137 in the windblown soil area and in the presence of uranium isotopes and other radionuclides such as Co-60, Eu-152, Eu-154, Sr-90. Based on the sampling and analytical results combined with the surface gamma-radiation survey conducted using the GPRS, a risk assessment was performed. Cesium-137 was identified as the primary contributor to the estimated total risk for all pathways. Cesium-137 was also the only gamma-emitting contaminant identified at the ARA-23 site, which is a key factor in using the GPRS to make quantitative measurements of the contamination. Figure 1 also provides the results of the in situ gamma survey of ARA-23.

2. OBJECTIVES

The primary objective for performing the GPRS calibration is to provide a method to convert the gross count rate information to a Cs-137 concentration at the ARA-23 site. The calibration will provide the basis that these types of systems can use to demonstrate the effectiveness of remedial actions. Additionally, the equipment calibration measurements will provide the GPRS calibration with a scan or moving minimum detectable concentration (i.e. scan MDC). This MDC should be a factor of two below the remedial action goal of 23 pCi/g as identified in the OU 5-12 record of decision (ROD) (DOE-ID 2000c) if the GPRS is to be used effectively in identifying Cs-137 contamination. The secondary

objective of the calibration is to present a method that could be used to calibrate the GPRS or similar real-time data and position acquisition systems for use at other radiologically contaminated soil sites.

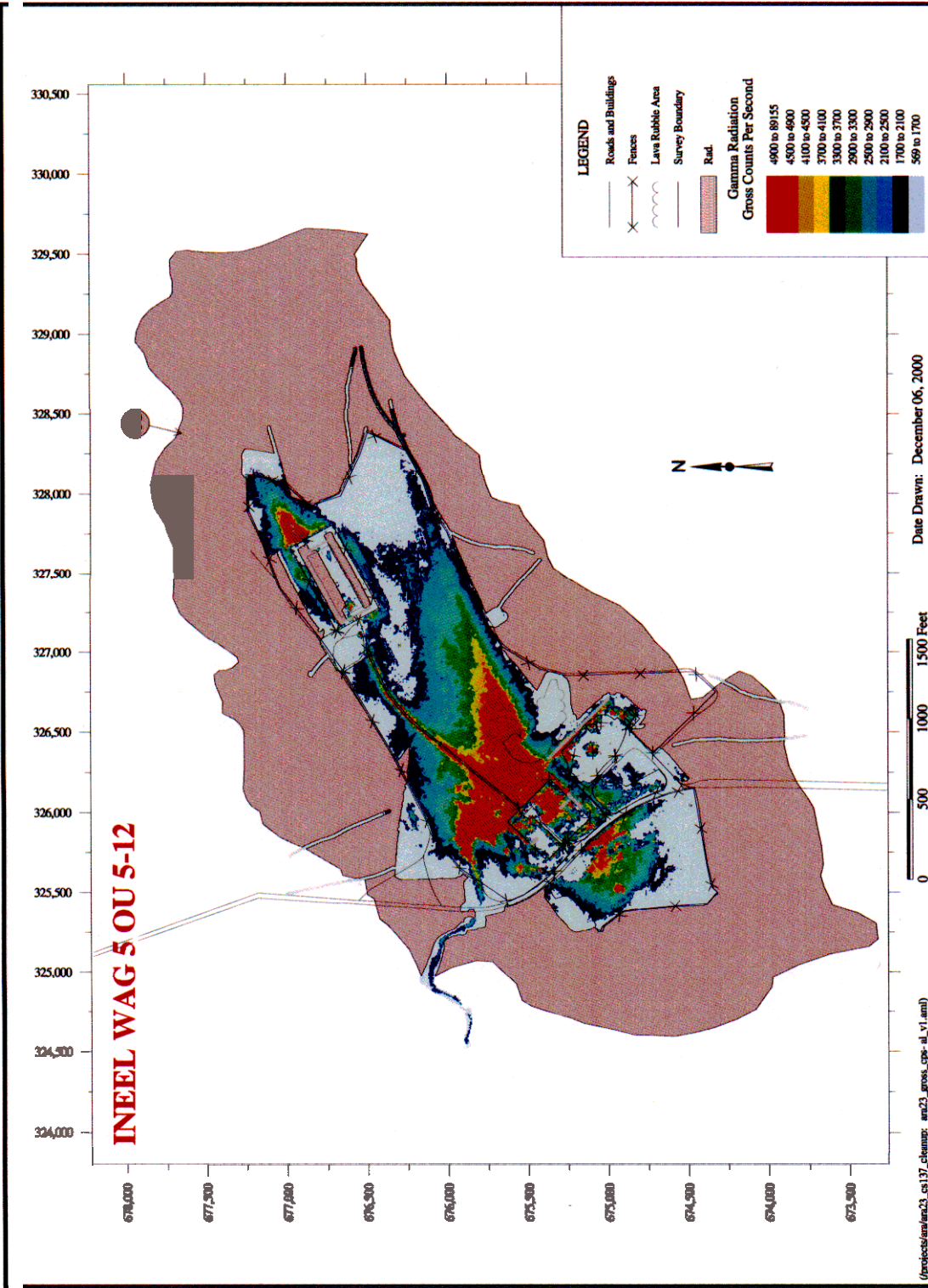


Figure 1. ARA-23 CERCLA site and gamma survey results.

3. METHODS AND MATERIALS

The basic method followed in the calibration of the GPRS is detailed in an EDF prepared in support of the *In-situ Gamma Radiation Survey at ARA-23 and ARA-24* (Josten 1997). The following sections describe the equipment and methodology used to collect and analyze the data.

3.1 INEEL Global Positioning Radiometric Scanner System

The INEEL GPRS is a mobile field survey system designed to rapidly characterize the areal extent of gamma-emitting radionuclide contamination of surficial soils. The GPRS consists of two large area plastic scintillation radiation detectors mounted to the front of a Humvee all-terrain vehicle that is equipped with global positioning system (GPS) navigation instruments. The detector height is fixed at a height of 3.3 ft. At this height, the detector has an approximate field of view diameter of 25 ft. The GPRS integrates the radiological data with the GPS data to provide information regarding the spatial distribution of gamma emitting contamination, in terms of gross counts per second, in the form of an area map.

3.2 ORTEC ISO-CART

The INEEL field based gamma spectrometry system measures radionuclide concentrations at areas where soils are contaminated with anthropogenic isotopes and that contain the usual naturally occurring nuclides. The system employs a standard coaxial germanium detector positioned at 1 m (3.3 ft) above ground and connected to an ORTEC Dart multichannel analyzer. The multichannel analyzer is connected to a field computer running the U. S. Department of Energy (DOE) Environmental Measurements Laboratory (EML) M1 software. This software uses internal efficiency calibration factors, attenuation corrections, and angular flux corrections to calculate and report the individual radionuclide specific activities (pCi/g) and associated uncertainties. The approximate field of view has a radius of 30 ft. with the HPGe detector positioned at a height of 3.3 ft. The system is calibrated on a daily basis prior to field measurements.

3.3 Calibration Measurement Methods

The contaminated portion of the ARA-23 site was completely surveyed by the GPRS, as shown in Figure 1. The initial survey was performed in 1997 in support of the in-situ gamma radiation survey for the OU 5-12 comprehensive remedial investigation/feasibility study (DOE-ID 1999). Data gaps were identified, and additional surveys were performed in 1999 and 2000 to fill the data gaps. The GPRS calibration data was collected during the months of October through November 2000. Data collection with the GPRS occurred first in October followed by the ISO-CART data collection in November. There was a brief period of precipitation between the GPRS and ISO-CART data points measurement; however, due to the radiological control conditions in place at the ARA-23 site, the soil was required to be dry prior to deployment of the ISO-CART. Additionally, during the measurement of the three calibration test points, approximately 1 in. of snow was present. The implications of the snow cover are discussed in Section 4.3. The calibration consisted of four primary steps: 1) GPRS background determination, 2) calibration measurement point selection, 3) calibration measurements, and 4) calibration data reduction.

3.3.1 GPRS Background Data Collection

Prior to calibrating the GPRS, the background response of the system (under field conditions) needs to be determined. The background measurement locations were selected near the ARA-23 site, but at a distance far enough away so that the GPRS detectors were not influenced by the Cs-137

contamination at the ARA-23 site. Two locations were arbitrarily selected based upon their apparent natural state (i.e., there was a considerable amount of sagebrush and grass, and the areas appeared to be previously undisturbed). These two areas are considered representative of the ARA background. The GPRS was driven through the background areas at the normal survey speed of approximately 5-mph, resulting in the collection of 782 background data points.

3.3.2 Calibration Measurement Point Selection

It was desired to calibrate the GPRS to a range of Cs-137 soil concentrations that included the 23 pCi/g remedial action goal. As a result, two transects across the windblown contamination footprint were selected for the calibration measurement locations. To provide statistically significant results in the data reduction, 15 individual measurement points were selected along each transect for a total of 30 calibration measurement points. Figure 2 shows the locations of the transects and associated calibration measurement points. The transects were labeled "A" and "B," with the individual calibration points numbered accordingly. Table 1 below provides the coordinates for the calibration measurement points.

Table 1. Calibration measurement point coordinate data^a.

Transect A			Transect B		
Point Designation	Easting	Northing	Point Designation	Easting	Northing
A1	326901.7	675614.2	B1	326628.2	676143.4
A2	326896	675651.0	B2	326636.1	676096.1
A3	326890.1	675687.7	B3	326643.2	676048.7
A4	326884.3	675723.5	B4	326649.8	676000.6
A5	326878.9	675759.9	B5	326656.7	675953.2
A6	326873.1	675796.0	B6	326663.3	675906.3
A7	326866.8	675832.6	B7	326669.9	675859.2
A8	326861.6	675868.8	B8	326677.0	675812.0
A9	326855.3	675905.0	B9	326684.3	675765.4
A10	326849.9	675940.6	B10	326691.0	675719.3
A11	326843.5	675975.4	B11	326697.9	675671.9
A12	326838.5	676012.0	B12	326704.4	675624.6
A13	326832.2	676048.9	B13	326711.2	675576.3
A14	326826.6	676085.6	B14	326718.9	675528.7
A15	326821.6	676121.3	B15	326726.0	675481.3
D1	326307	675911.7			
D2	326447.4	676086.4			
D3	326760.8	676413.3			

a. Coordinates in NAD 27, State Plane.

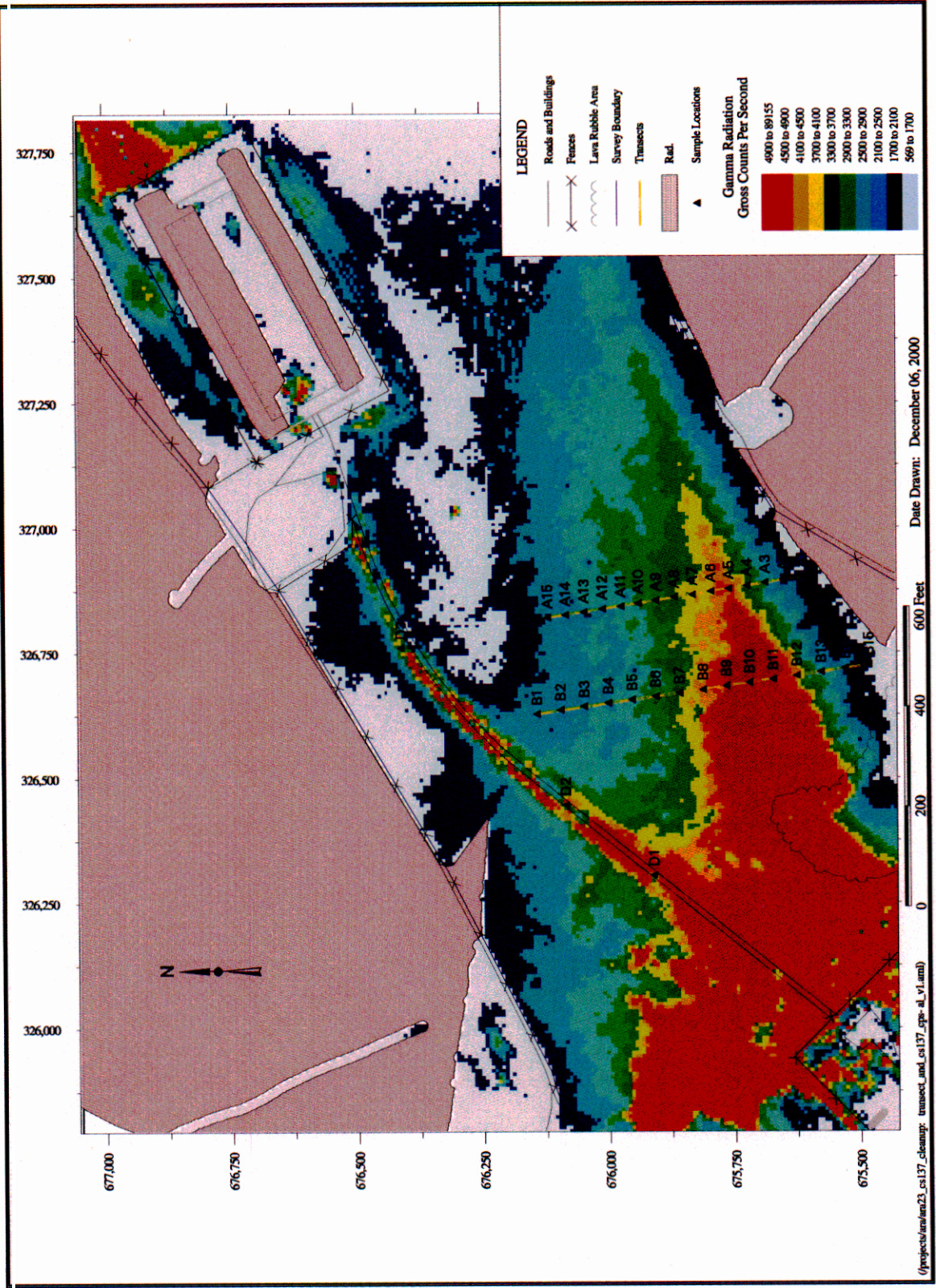


Figure 2. Detail of study area showing calibration measurement point locations.

Three points (designated D1, D2, and D3) located along the haul road were selected as test points to evaluate the accuracy of the GPRS calibration. Table 1 also contains the coordinate data for D-series measurement points.

3.3.3 Calibration Measurements

The calibration measurements were comprised of a series of radiation measurements. These included calibration points A1-A15 and B1-B15 using the GPRS and the ISO-CART system. Initially, the GPRS was used to measure the points along Transects A and B, traveling at a speed of 5-mph. Gross count rate and position data were collected and stored every second along each transect. The GPRS was positioned such that the calibration measurement points were centered beneath the GPRS radiation detectors (i.e., the wheels straddled the transect line). Next, the ISO-CART was used to measure each calibration point individually to quantify the Cs-137 contamination in the area seen by the detector. At this point it is important to note that the fields of view for the GPRS and the ISO-CART are comparable, as discussed in Sections 3.1 and 3.2 above. The ISO-CART system was positioned with the detector “looking” straight down on the measurement point. A count time of 600 seconds was used for the ISO-CART measurements.

GPRS and ISO-CART measurements were also made at points D1, D2, and D3. These points, as noted above, were selected as test points to evaluate the accuracy of the GPRS calibration.

3.4 Data Reduction

Following data collection, detailed data analyses were performed using Microsoft Excel. The data reduction methods employed included statistical analysis of data using the analysis routines in Excel. The GPRS background data were analyzed to determine the average background for the ARA area. In turn, the net count rates (gross counts minus the background) for the GPRS were compared to the reported Cs-137 values from the ISO-CART system. The Cs-137 concentrations reported by the ISO-CART system assume a 1-in. uniform distribution of the contamination in the surficial soils. This allowed for a direct comparison of the Cs-137 concentration of the soils to the observed net count rate from the GPRS. A relationship between Cs-137 and GPRS net count rates was then established. Additionally, it was desirable to identify *a priori*, the minimum detectable count rate or minimum detectable concentration for Cs-137, for the GPRS system to verify that it was below the remedial action goal. The following sections of this EDF present the results of the data analysis and describe the relationship between the GPRS net count rate and Cs-137 soil concentrations at the ARA-23 CERCLA site. The raw data associated with this study are located in the WAG-5 project files.

4. RESULTS AND DISCUSSION

The following sections present the results of the detailed data analyses that were performed to reduce the radiological data to a usable format and subsequent analyses that determined calibration parameters for the GPRS system.

4.1 GPRS Background Determination

The GPRS background count rate was determined in order to obtain the response of the detector to the naturally occurring radioactive material in the soils near the ARA-23 site. Two background data files were combined to make a large pool of data consisting of 782 data points. A statistical analysis was performed on the data, resulting in an average background count rate of 1032.8 ± 63.8 counts per second (cps). The statistical summary for the background data set is presented in Table 2, and a graphical presentation is shown in Figure 3.

GPRS Background Count Rate

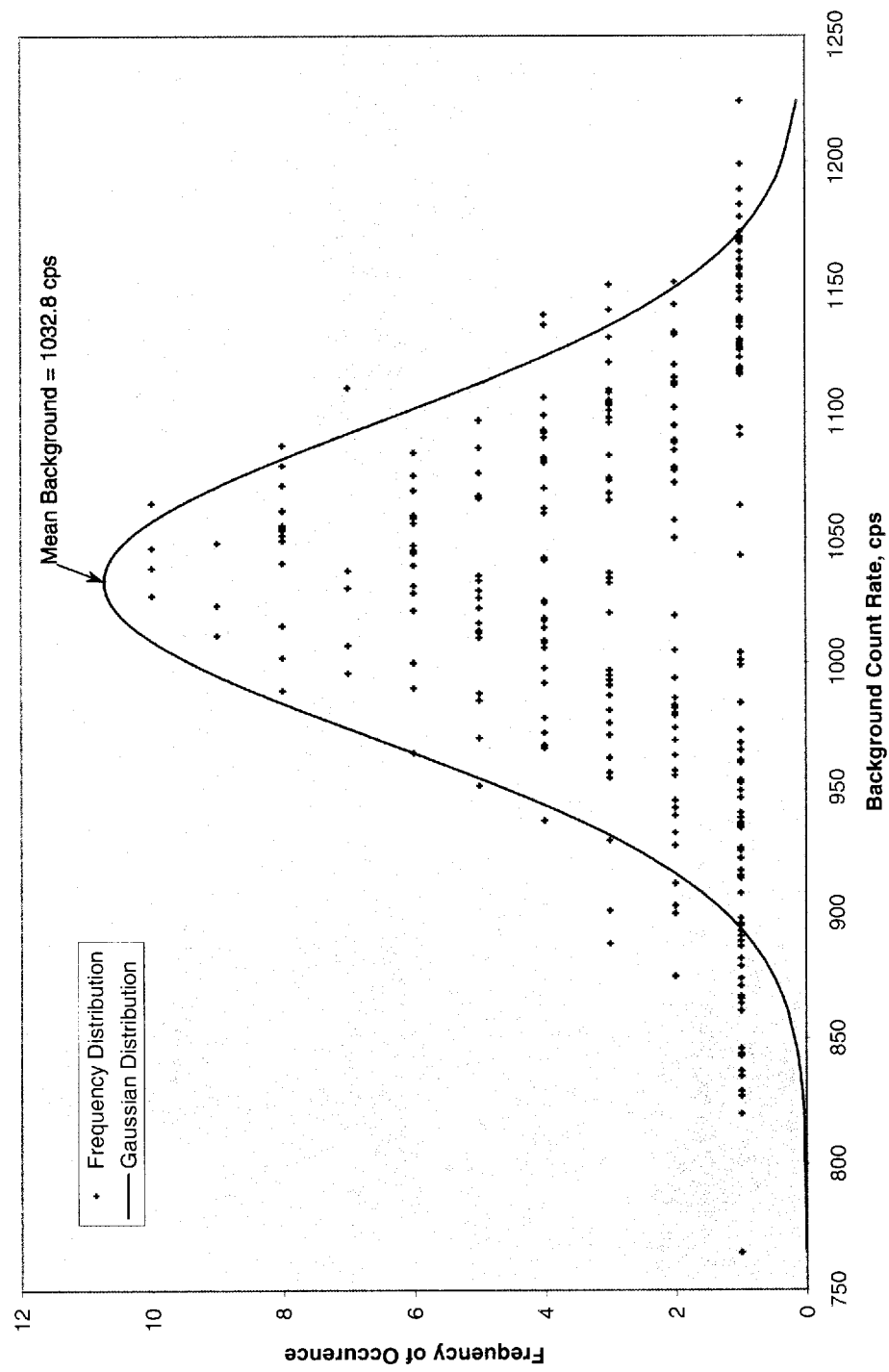


Figure 3. GPRS background count rate distribution.

Table 2. Statistical summary of background data set.

Number of Data Points	782
Minimum	765 cps
Maximum	1224 cps
Mean	1032.8 cps
Standard Deviation	63.8 cps
Standard Error	2.3

Figure 3 shows the frequency distribution of the 782 background data points. Additionally, a Gaussian distribution was fit to the data showing that the data are distributed normally about the mean value.

4.2 GPRS Cs-137 Calibration Curve

Measurements of the 30 calibration points along Transects A and B with the GPRS and the ISO-CART were completed in support of the GPRS calibration. The previously described measurement methods, and the data analysis and results that follow, were performed following the methodology presented by Josten (1997).

The GPRS data points on these plots correspond to the single point along the transect closest to the calibration measurement point. This is the easiest and most practical way to handle the data produced by the GPRS. It should be noted that a comparison was made between the single point GPRS value and an average of the five closest GPRS values to the surveyed calibration point, and there was little observable and no statistical difference between the two sets of values. This is demonstrated in Figures 4 and 5 for Transects A and B.

The first step in establishing a relationship between the GPRS net count rate data and the ISO-CART Cs-137 reported concentrations was to plot the GPRS and ISO-CART data as a function of position. Figures 6 and 7 show the profile of Transects A and B in terms of GPRS single point net count rate and Cs-137 concentrations with respect to the measurement point Northing coordinate value. As can be seen from these two figures, the relative response of both the GPRS and ISO-CART demonstrate that the two systems respond to the activity distribution across the transect in an almost identical fashion. There is, however, slightly more deviation observed in Transect A than there is in Transect B. Additionally, as can be seen from Figures 6 and 7, the Cs-137 concentration ranges, as reported by the ISO-CART, range from approximately 5 to 60 pCi/g, which encompass the 23 pCi/g remedial action goal.

The next step in establishing calibration factors was to plot the reported Cs-137 concentrations with respect to the GPRS net count rate. Table 3 lists the data values for each calibration point along the transects. Figure 8 is a graphical representation of the data.

Transect A Single Point v. 5-Point Comparison

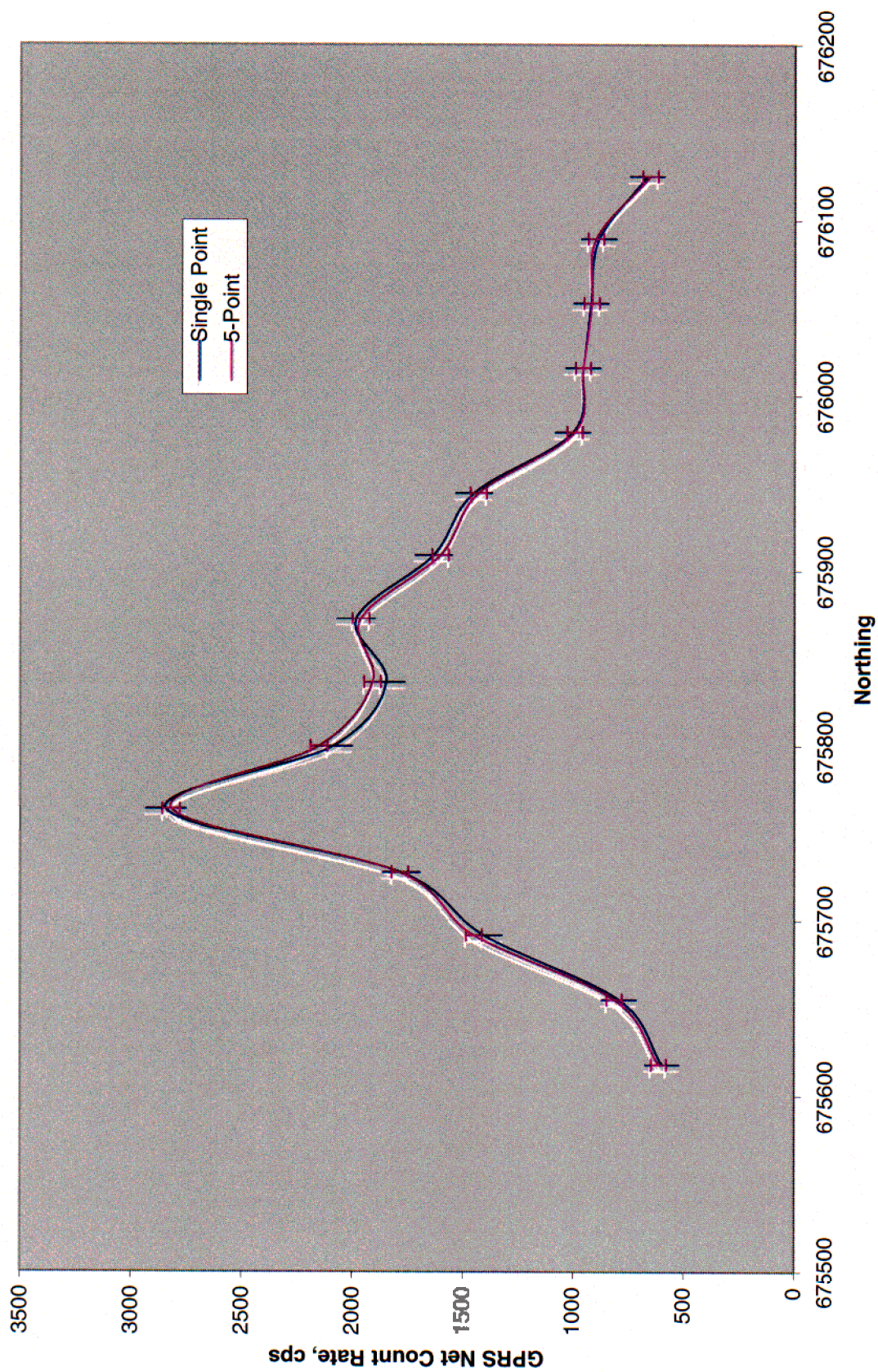


Figure 4. Transect A single-point versus five-point average count rate comparison.

Transect B Single Point v. 5-Point Comparison

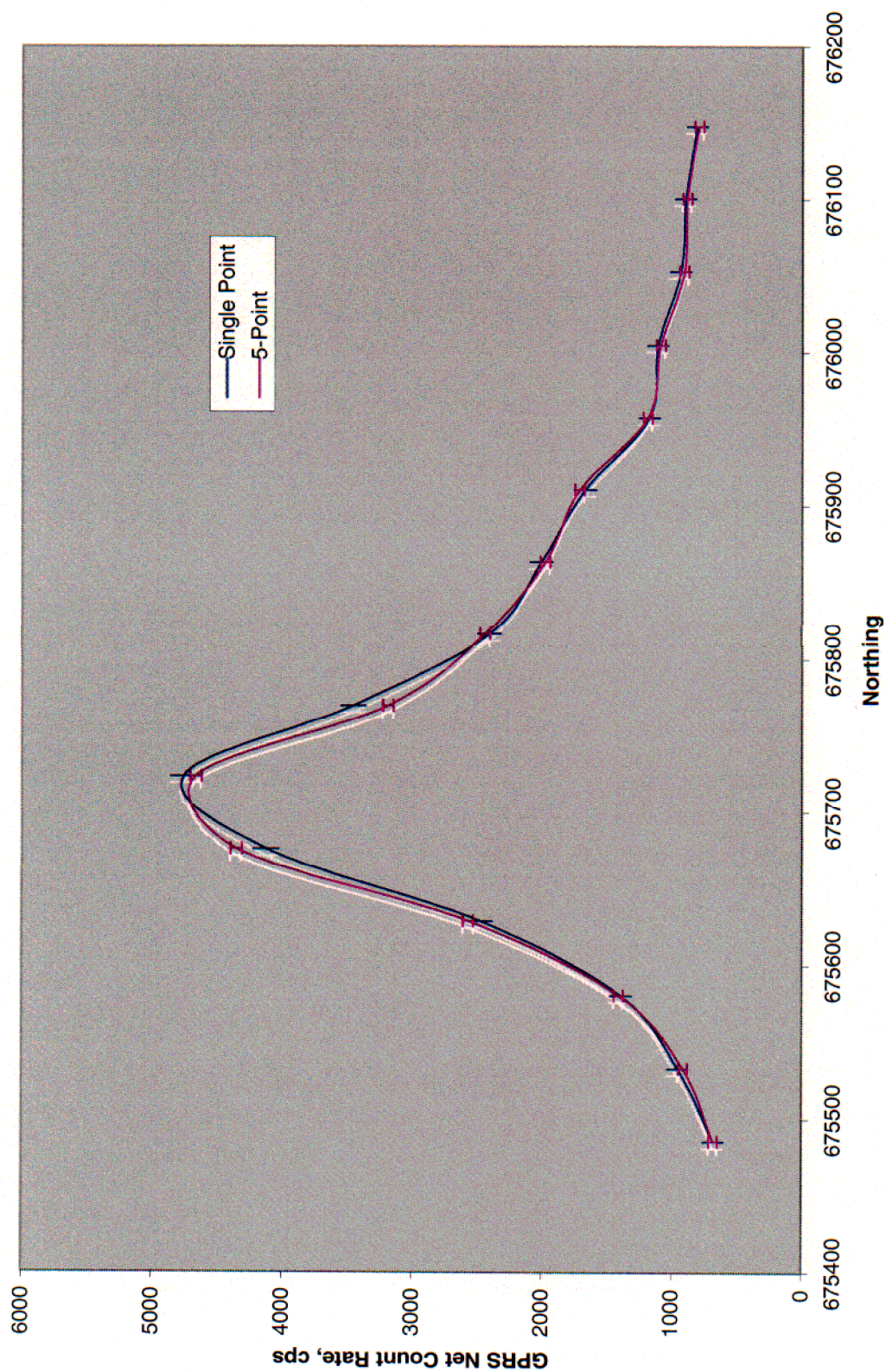


Figure 5. Transect B single-point versus five-point average count rate comparison.

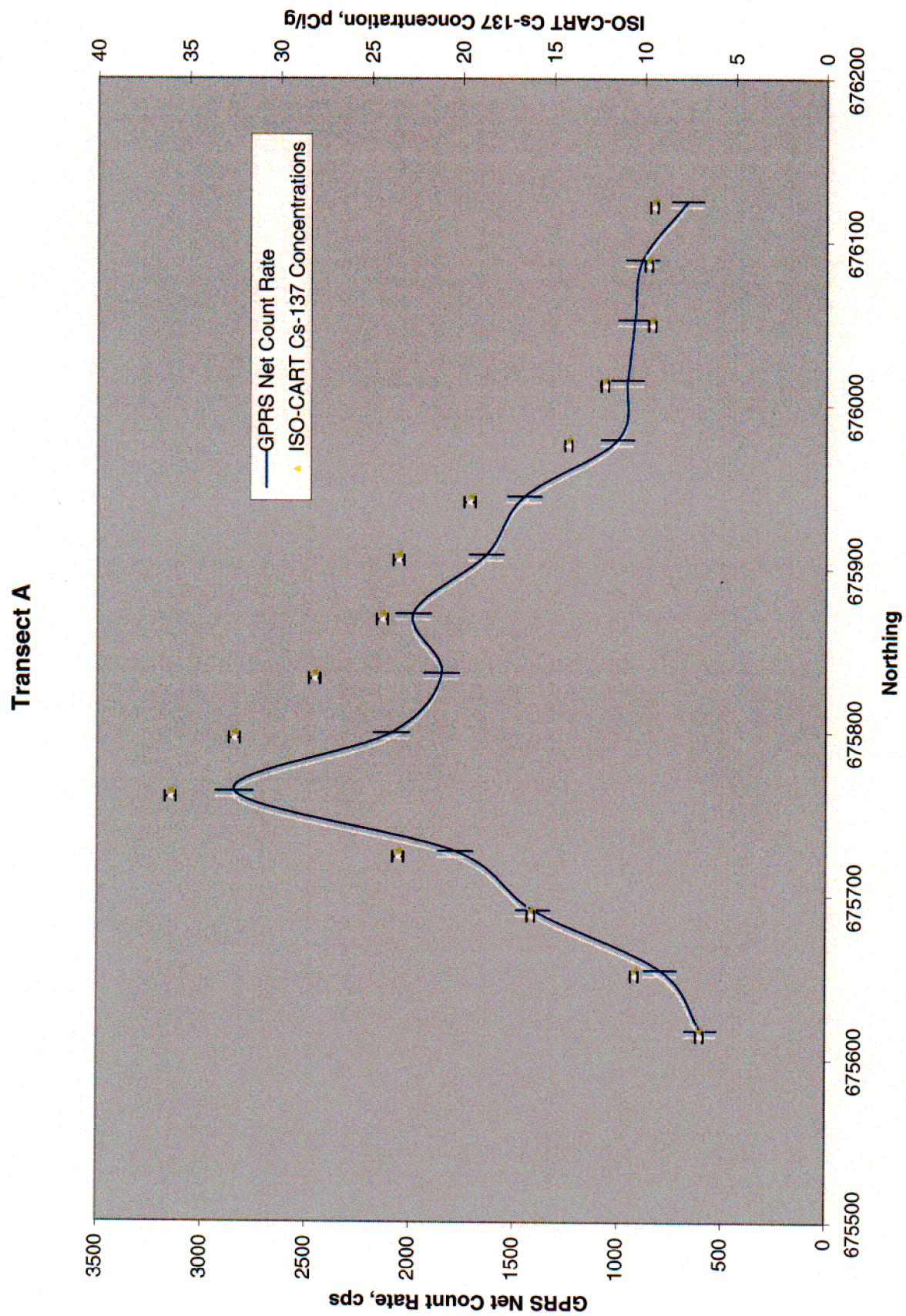


Figure 6. Transect A detail with GPRS count rate and ISO-CART results.

Transect B

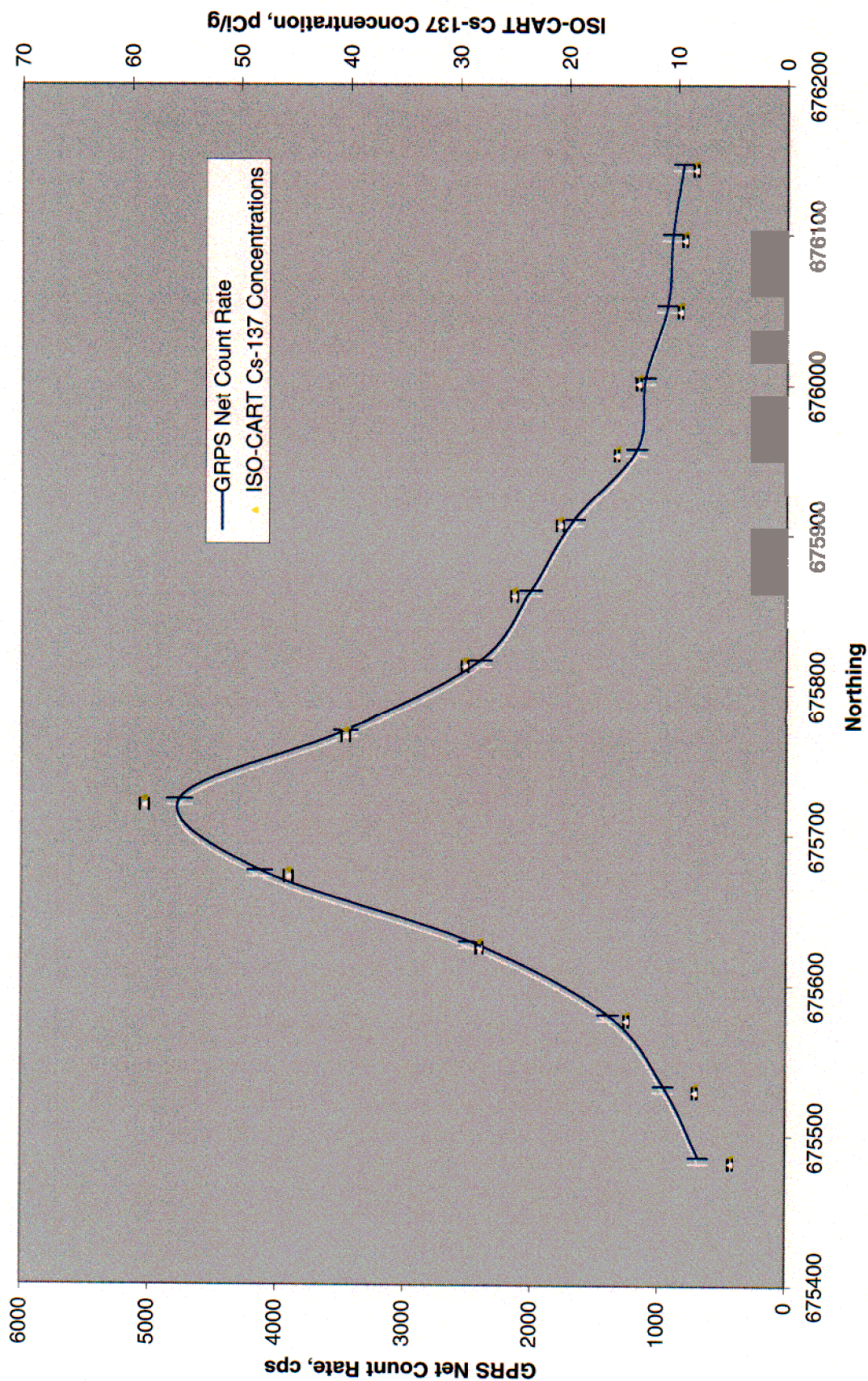


Figure 7. Transect B detail with GPRS count rate and ISO-CART results.

Transects A & B GPRS Calibration Curve

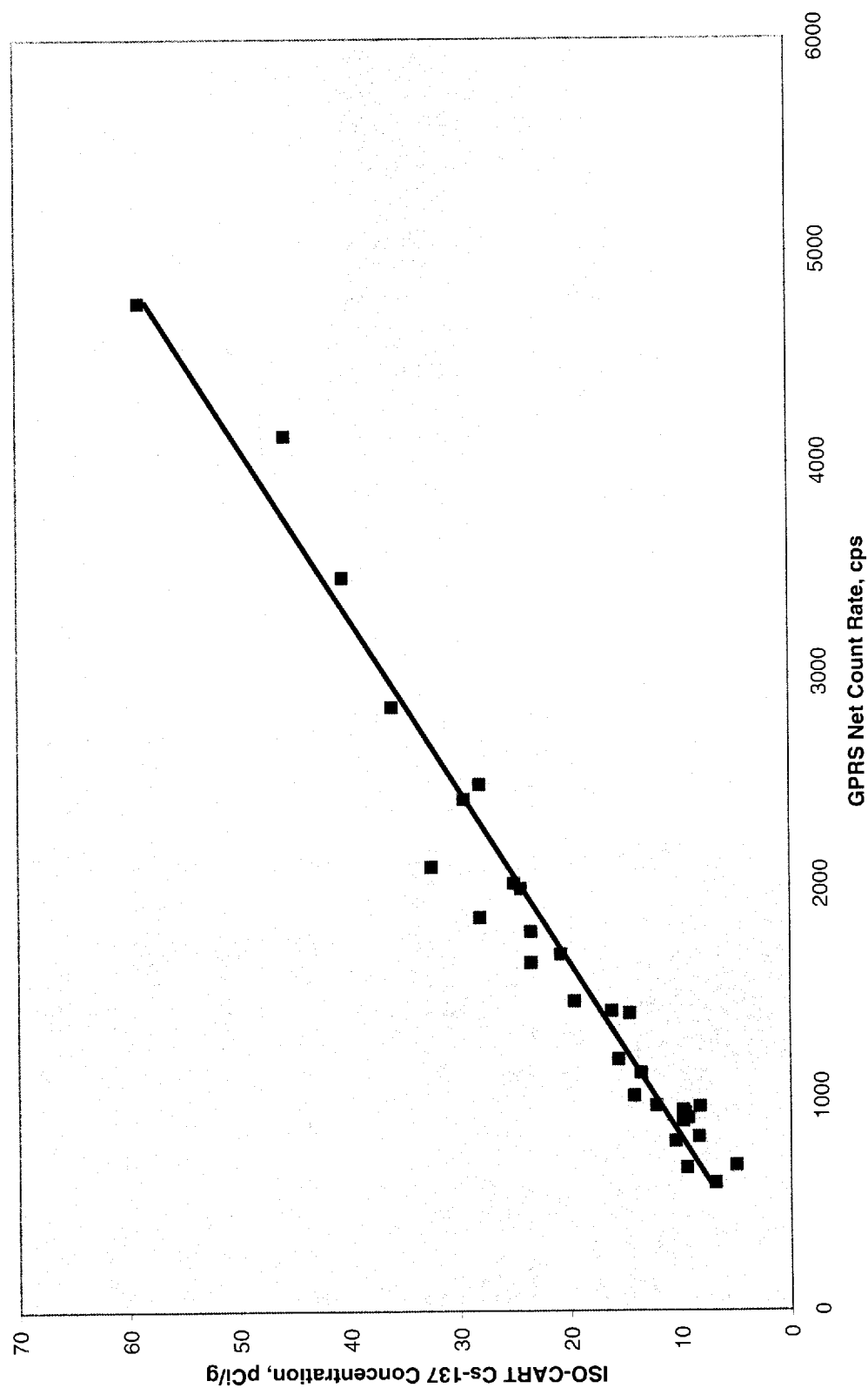


Figure 8. GPRS calibration curve. Transect A and Transect B data combined.

Table 3. Calibration point data values^a.

Calibration Point Designation	GPRS Net Count Rate, cps	ISO-CART Cs-137 Concentration, pCi/g	GPRS Calculated Cs-137 Concentration, pCi/g
A1	602.2 ± 75.5	6.9 ± 0.1	7.4 ± 1.0
A2	797.2 ± 76.8	10.5 ± 0.1	9.8 ± 1.0
A3	1409.2 ± 80.7	16.2 ± 0.1	17.2 ± 1.0
A4	1783.2 ± 83.0	23.5 ± 0.15	21.8 ± 1.1
A5	2845.2 ± 89.2	36 ± 0.15	34.8 ± 1.1
A6	2090.2 ± 84.8	32.5 ± 0.15	25.5 ± 1.1
A7	1851.2 ± 83.4	28.1 ± 0.15	22.6 ± 1.1
A8	1987.2 ± 84.2	24.4 ± 0.15	24.3 ± 1.1
A9	1638.2 ± 82.1	23.5 ± 0.15	20.0 ± 1.0
A10	1456.2 ± 81.0	19.6 ± 0.15	17.8 ± 1.0
A11	1010.2 ± 78.2	14.2 ± 0.1	12.4 ± 1.0
A12	963.2 ± 77.9	12.2 ± 0.1	11.8 ± 1.0
A13	928.2 ± 77.7	9.6 ± 0.1	11.4 ± 1.0
A14	892.2 ± 77.4	9.8 ± 0.1	10.9 ± 1.0
A15	674.2 ± 76.0	9.5 ± 0.1	8.3 ± 1.0
B1	817.2 ± 76.9	8.4 ± 0.1	10.0 ± 1.0
B2	904.2 ± 77.5	9.4 ± 0.1	11.1 ± 1.0
B3	943.2 ± 77.8	9.8 ± 0.1	11.6 ± 1.0
B4	1118.2 ± 78.9	13.6 ± 0.1	13.7 ± 1.0
B5	1182.2 ± 79.3	15.6 ± 0.1	14.5 ± 1.0
B6	1677.2 ± 82.3	20.8 ± 0.15	20.5 ± 1.1
B7	2013.2 ± 84.4	25 ± 0.15	24.6 ± 1.1
B8	2410.2 ± 86.7	29.5 ± 0.15	29.4 ± 1.1
B9	3460.2 ± 92.5	40.4 ± 0.2	42.3 ± 1.2
B10	4762.2 ± 99.3	58.8 ± 0.2	58.1 ± 1.3
B11	4132.2 ± 96.1	45.6 ± 0.2	50.5 ± 1.2
B12	2479.2 ± 87.1	28.1 ± 0.15	30.3 ± 1.1
B13	1398.2 ± 80.6	14.6 ± 0.1	17.1 ± 1.0
B14	958.2 ± 77.9	8.3 ± 0.1	11.7 ± 1.0
B15	684.2 ± 76.1	5 ± 0.1	8.4 ± 1.0
a.	Measurement uncertainties reported at 1σ.		

As can be seen from Figure 8, the relationship between the GPRS net count rate and the ISO-CART reported Cs-137 concentration is linear. This observation was also made by Josten, demonstrating that the GPRS is still functioning in a linear manner over the observed Cs-137 concentration range. Linear regression analysis performed on the data resulted in an equation that may be used to convert net count rate data from the GPRS to Cs-137 concentrations at the ARA-23 site. The general form of the equation is as follows:

$$C = K_1 \cdot A + K_2.$$

Where:

C = Cs-137 concentration

A = Observed net GPRS count rate

K_1, K_2 = Best fit parameters as determined by linear regression analysis.

Values for K_1 and K_2 , as determined by linear regression, are as follows:

K_1 = 0.0122 (pCi/g)/cps

K_2 = 0.0455 pCi/g.

This results in the following equation:

$$C = 0.0122 [(pCi/g)/cps] \cdot A (cps) + 0.0455 (pCi/g).$$

Similarly, the uncertainty in the Cs-137 concentration, as reported by the GPRS data is:

$$\sigma_C = 0.0122 [(pCi/g)/cps] \cdot \sigma_A (cps) + 0.0455 (pCi/g).$$

Where:

σ_C = Cs-137 uncertainty

σ_A = Net count rate uncertainty.

The net count rate uncertainty, σ_A , may be calculated as follows (Knoll 1989):

$$\sigma_A = \sqrt{\sigma_G^2 + \sigma_{Bkg}^2}.$$

Where:

σ_G = Gross count rate uncertainty

σ_{Bkg} = Background count rate uncertainty.

The background count rate uncertainty, σ_{Bkg} , is given by the standard deviation as reported in Table 2. This value is 63.8 cps. The gross count rate uncertainty, σ_G , based on nuclear counting statistics, is

simply the square root of the gross counts divided by the count time (Knoll 1989), which, for the GPRS measurements, are all 1-second.

4.3 GPRS Calibration Accuracy

The accuracy of the GPRS calibration was evaluated using the following two methods: 1) comparison of the GPRS calculated Cs-137 concentrations at the calibration points along Transects A and B with the ISO-CART data, and 2) an independent comparison between GPRS calculated concentrations and ISO-CART reported concentrations at points D1, D2, and D3.

Figure 9 compares the GPRS calculated concentrations with the ISO-CART reported concentrations for the calibration points along Transects A and B. As expected, the correlation is linear, and shows a nearly 1 to 1 relationship between the two data sets (listed in Table 3) as indicated by the slope of the line (0.99).

Three additional measurement points (D1, D2, and D3) were identified at the ARA-23 site to verify the accuracy of the new GPRS calibration equation in determining the Cs-137 concentration in soils. Table 4 lists and compares the results of the GPRS measurements with the ISO-CART measurements for measurement points D1, D2, and D3. The GPRS values are consistently high for these measurement points, averaging 22.9%. The two potential contributors to this bias are: 1) the ISO-CART measurements were made with approximately 1 in. of snow on the ground, and 2) the Cs-137 contamination along the haul road (where D1, D2, and D3 are located) is distributed deeper than the assumed 1-in. windblown contamination distribution associated with Transects A and B.

It is most likely that the snow layer on the ground is the primary contributor to the bias. This is due to the attenuation of the Cs-137 gamma-rays by the snow. As a result, the computed Cs-137 concentrations reported by the ISO-CART are biased low. It should be noted that the original ISO-CART data for points D1, D2 and D3 were increased by 25% to account for the snow layer. This was based on observed bias in ISO-CART measurements of points B13 and B14 before and after the snowfall. The actual snow depths at points B13, B14, D1, D2 and D3, within the ISO-CART field of view, were not measured. Additionally, the deeper distribution of Cs-137 along the SL-1 haul road would bias the GPRS data high due to the increased signal as seen by the detector. As a result, it is possible that a 25% increase at locations D1, D2 and D3 was less than the true correction.

4.4 GPRS Scan MDC

A question that is often posed with regards to radiation measurement systems is "*What is the smallest amount of activity that can be seen with this system?*" The GPRS is the system in question in this instance, and the *a priori* detection limit is the system parameter that is desired. Typical protocol for laboratory instrumentation is to have a lower limit of detection that is at least a factor of ten less than the action level, or remedial action goal. The U. S. Nuclear Regulatory Commission (NRC) has published guidance for determining lower limits of detection, or minimum detectable concentrations (MDCs) for survey instrumentation (NRC 1997). The following is a calculation of the GPRS scan MDC as determined from NUREG 1507.

GPRS v. ISO-CART Comparison of Reported Cs-137 Concentrations

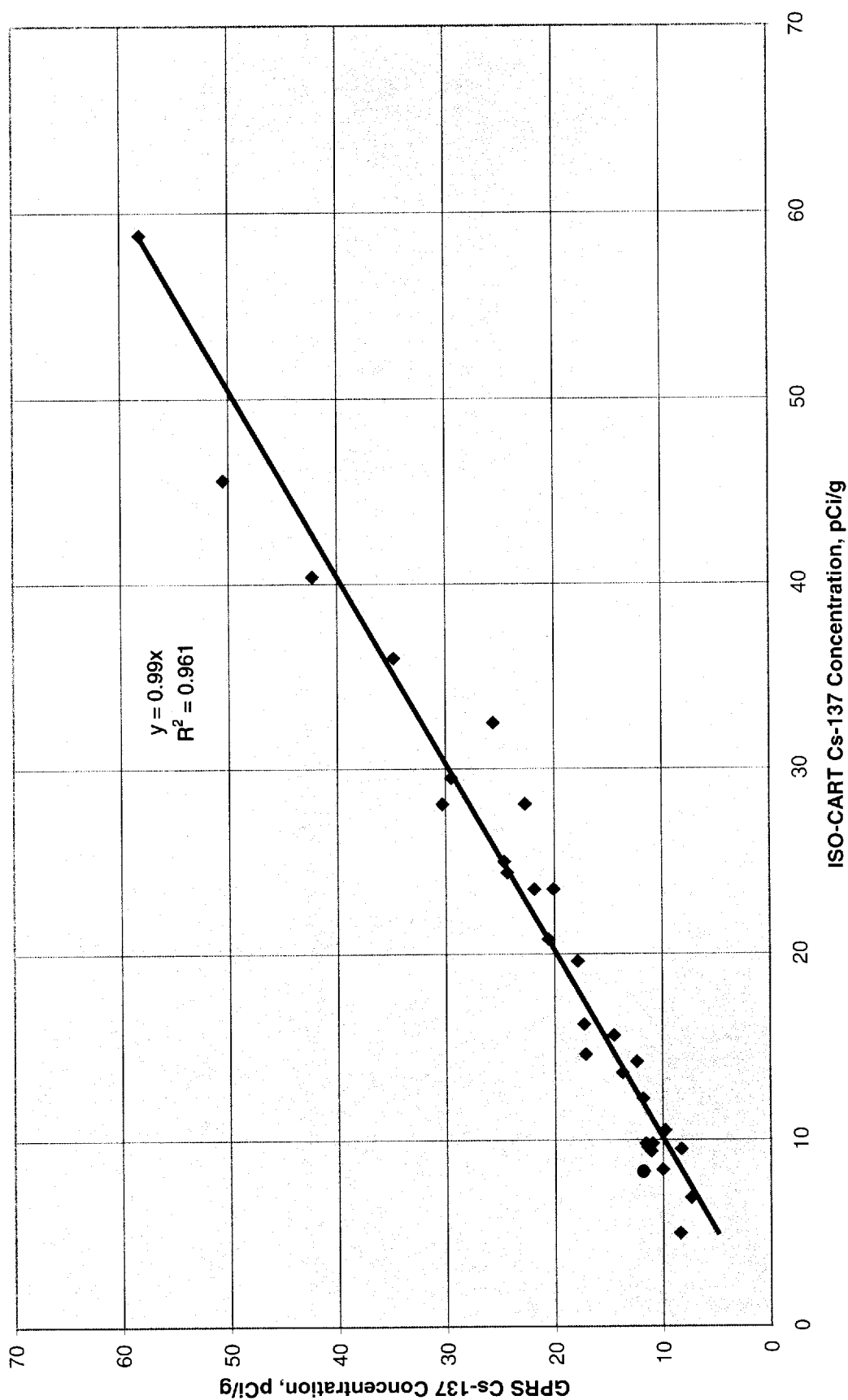


Figure 9. Comparison of GPRS and ISO-CART Cs-137 concentrations.

Table 4. GPRS calibration accuracy^a.

Point Designation	Reported Cs-137 Concentration, pCi/g		Difference
	GPRS	ISO-CART	
D1	31.7 ± 0.5	28.7 ± 0.4	+9.5%
D2	27.7 ± 0.5	18.5 ± 0.3	+33.2%
D3	23.8 ± 0.5	17.6 ± 0.4	+26.1%

a. Measurement uncertainties reported at 1σ.

The minimum detectable number of net source counts, s_i , during a given count interval, i , is given by (NRC 1997):

$$s_i = d' \sqrt{b_i}.$$

Where:

s_i Minimum detectable number of net source counts during a count interval, i

d' Index of sensitivity

i Count interval

b_i Background count rate during count interval i

The specified count interval, i , for the GPRS is 1 second, and the background count rate is taken as 1,032.8 cps. The index of sensitivity, d' , is a value that reflects the acceptable Type I and Type II error rates. Values for the index of sensitivity, d' , have been calculated by transforming Type I and Type II error rates to z values, and taking the difference. These values are tabulated in Table 6.1 of NUREG 1507 (NRC 1997). Using Type I and Type II error values of 0.05 and 0.20, a value of 2.48 is obtained for the index of sensitivity. Therefore, the minimum detectable number of net source counts for the GPRS is then;

$$s = 2.48 \cdot \sqrt{1032.8}$$

$$s = 79.7 \text{ counts.}$$

Using the 1 second time interval of the GPRS, the minimum detectable count rate, $MDCR$, is then:

$$MDCR = 79.7 \text{ cps.}$$

The desired value, however, is the minimum detectable concentration for Cs-137. This can be calculated using the conversion equation derived in Section 4.2, substituting the MDC for the concentration, C :

$$MDC = 0.0122 [(pCi / g) / cps] \cdot 79.7 (cps) + 0.0455 (pCi / g)$$

$$MDC = 1.0 \text{ pCi / g.}$$

The calculated scan MDC for the GPRS is found to be well below the 23 pCi/g remedial action goal for the Cs-137 contaminated soils at ARA-23.

5. SUMMARY AND RECOMMENDATIONS

Radiation measurements were made at the ARA-23 CERCLA site using the INEEL GPRS and ISO-CART systems. A calibration function was developed for calculating and converting GPRS net count rate data to Cs-137 concentrations at the ARA-23 site. Additionally, it was shown that the accuracy of the GPRS measurements, with respect to the ISO-CART, was within 25%, which for the purposes of field screening, is adequate. Additionally, the utility of the GPRS in identifying Cs-137 hot spots at or above the 23 pCi/g remedial action goal was verified with the calculation of the minimum detectable concentration. As shown in Section 4.4, the scan MDC for the GPRS is 1.0 pCi/g.

Although the study presented here demonstrates that the GPRS can be used to quantify Cs-137, the following precautions must be observed:

- The calibration developed here is specific to the ARA-23 CERCLA site, and specific to Cs-137. This calibration **should not** be applied to GPRS data at any other contaminated site. If it is determined that quantitative measurements using the GPRS at other contaminated sites would be cost effective, then a study similar to the one presented here, including determination of a site specific background, could be conducted. Additionally, it must be verified through analytical samples and/or ISO-CART measurements that the contamination is associated with a single gamma emitter (i.e. Cs-137). If multiple gamma emitters are present, it may still be possible to use the GPRS; however, a consistent ratio must be present between the gamma emitters.
- The GPRS background count rate for the ARA-23 site should be re-evaluated just prior to the OU 5-12 Phase II soil removal action, currently scheduled for FY 2004. Changes or modifications to the GPRS may affect the system response to radiation. Additionally, changes to the soil, such as removal of the top layer, may result in lower background count rates; due primarily to the removal of the Cs-137 that is present due to atmospheric weapons testing. The average background Cs-137 concentration, due to atmospheric weapons testing and INEEL operations, is 0.44 pCi/g (Rood et al. 1996). It is recommended that prior to the OU 5-12 Phase II soil removal a background study be conducted. This study can be conducted by excavating the top 3 in. of soil from a previously undisturbed area and by measuring the background count rate at a minimum of 30 locations through use of the GPRS. The GPRS collects a data point every second, therefore a fairly small area would require excavation (i.e., 60×300 ft, 1800 ft²). Based on the calculations presented in this EDF, the probability of making a Type II error is 20%; however, if the background count rate of excavated soils is statistically different from the background count rate of undisturbed soils, then the probability of committing a Type II error will also increase. The risk associated with this would be high considering that hot spots above the remedial action goals could be missed resulting in the site being incorrectly declared "clean." Accurate field measurements are required to ensure that only contaminated soil is removed, thereby minimizing the disposal volume, and ensuring that declaring the site clean after the remedial action is correct.
- The calibration equation presented in this report assumes a 1-in. uniform distribution of the Cs-137. An evaluation of the depth distribution presented in Josten (1997) demonstrates that this is an accurate depiction of the actual distribution of Cs-137 at ARA-23. In instances where the contamination is actually distributed deeper than 1 in. (such as the SL-1 haul road), the GPRS response may overestimate the concentrations for the first few inches of soil. However, as soil is removed, the actual distribution will approach the assumed 1-in. distribution resulting in more accurate GPRS measurements.

6. REFERENCES

- DOE-ID, September 2000a, *Waste Area Group 5 Remedial Design/Remedial Action Work Plan, Phase II, (Draft)*, DOE/ID-10798, U.S. Department of Energy, Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; Idaho Department of Environmental Quality.
- DOE-ID, September 2000b, *Field Sampling Plan for Waste Area Group 5, Remedial Design, Phase II, (Draft)*, DOE/ID-10808, U.S. Department of Energy, Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; Idaho Department of Environmental Quality.
- DOE-ID, January 2000c, *Record of Decision, Power Burst Facility and Auxiliary Reactor Area, Operable Unit 5-12*, DOE/ID-10700, U.S. Department of Energy, Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; Idaho Department of Environmental Quality.
- DOE-ID, January 1999, *Waste Area Group 5 Operable Unit 5-12 Comprehensive Remedial Investigation/Feasibility Study*, DOE/ID-10607, U.S. Department of Energy, Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; Idaho Department of Environmental Quality.
- DOE-ID, May 1997, *Final Work Plan for Waste Area Group 5 Operable Unit 5-12 Comprehensive Remedial Investigation/Feasibility Study*, DOE/ID-10555, Rev. 0, U.S. Department of Energy, Idaho Operations Office.
- Josten, N., 1997, *In Situ Gamma Radiation Survey at ARA-23 and ARA-24*, Engineering Design File ER-WAG5-104, Rev. 2, Idaho National Engineering and Environmental Laboratory.
- Knoll, G. F., 1989, *Radiation Detection and Measurement*, John Wiley & Sons, New York.
- NRC, December 1997, *NUREG-1507 – Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, NUREG-1507, U.S. Nuclear Regulatory Commission.
- Rood, S. M., G. A. Harris, and G. J. White, August 1996, *Background Dose Equivalent Rates and Surficial Soil Metal and Radionuclide Concentrations for Idaho National Engineering Laboratory*, INEL-94/0250, Rev. 1, Idaho National Engineering Laboratory.